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Materials Technology
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STRUCTURES AND PROPERTIES OF THE REFRACTORY SILICIDES Ti_5 Si_3 AND $TiSi_2$ AND Ti-Si-(Al) EUTECTIC ALLOYS

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  - Physical properties
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    - fracture toughness
    - creep properties

    temperatur-dependent
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- Hypoeutectic and directionally solidified eutectic α-Ti-Ti_5Si_3 alloy
  - Microstructures
    - optical and SEM images
  - Physical properties
    - thermal expansion coefficient α (T)
    - Young`s moduli E (T)
  - Mechanical properties
    - yield stress
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- Conclusions

Report Documentation Page

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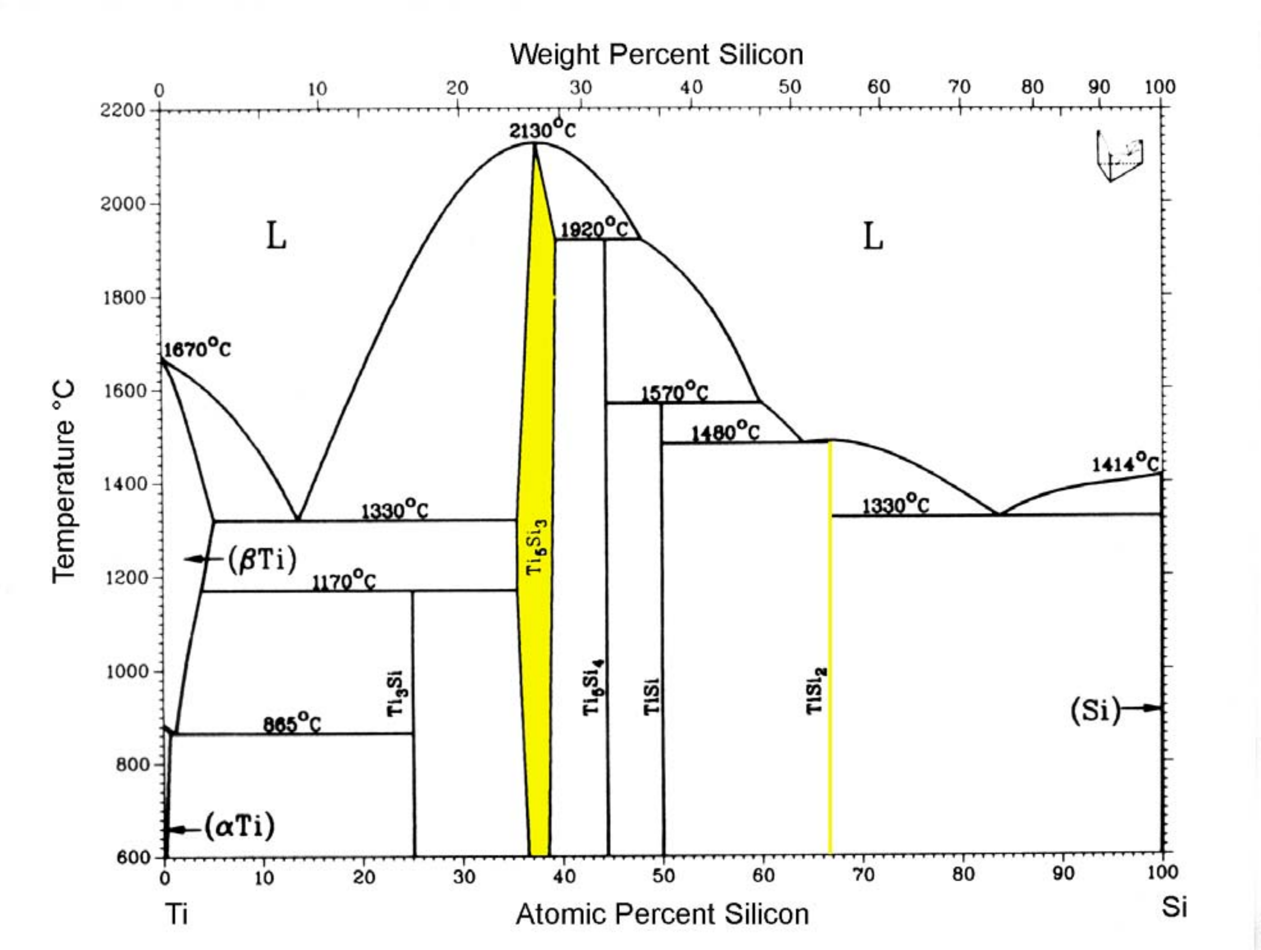
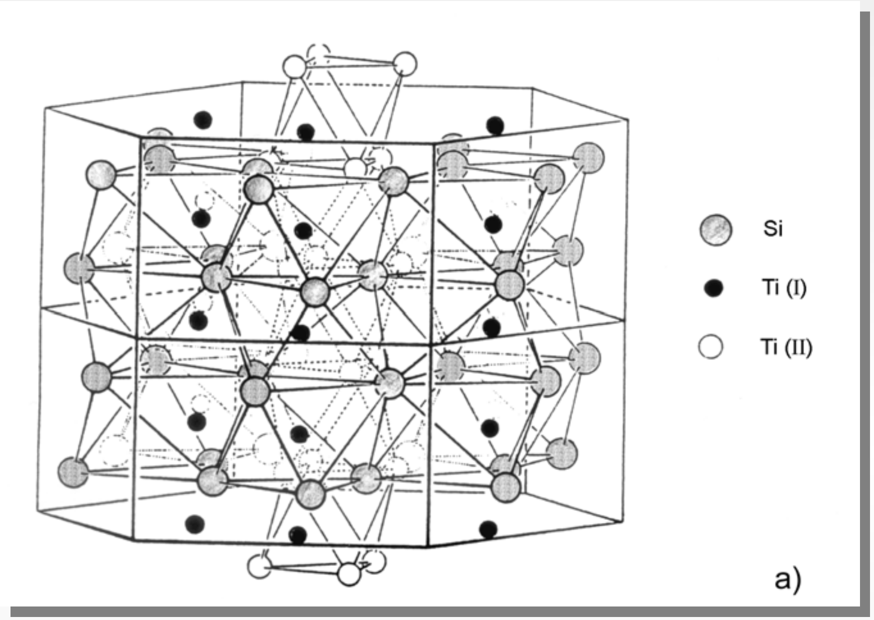
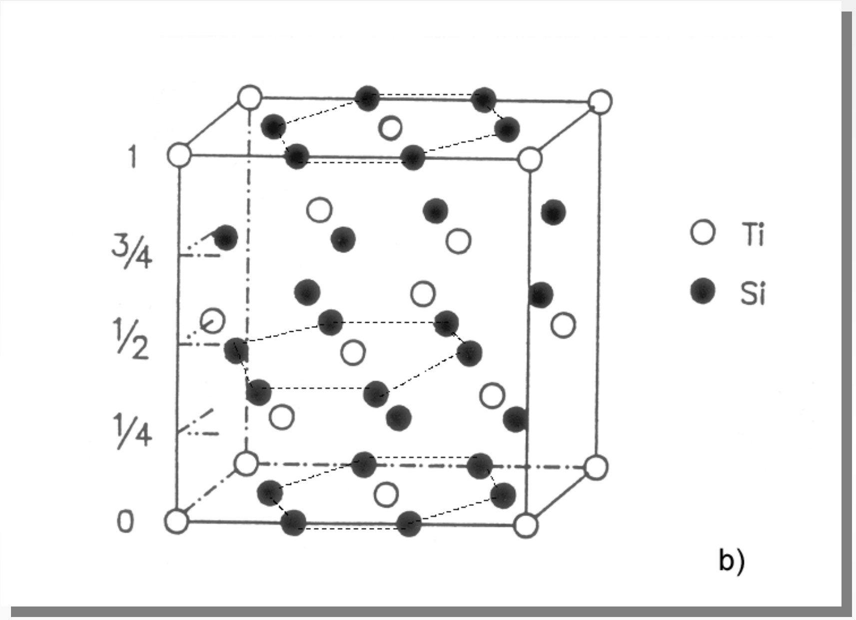


Equilibrium phase diagram of the binary Ti-Si system





Ti_5Si_3 $TiSi_2$

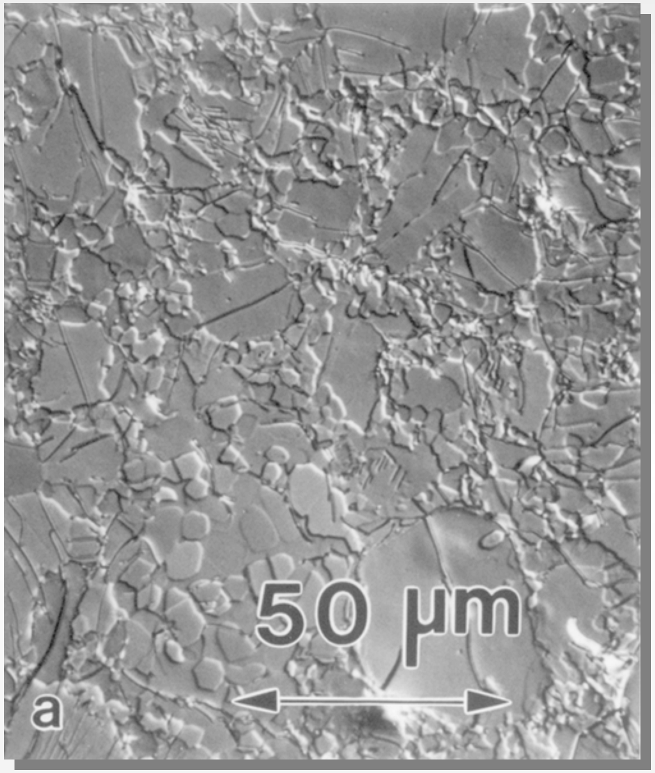
Crystal structures of the intermetallic and compounds.

complex hexagonal $D8_8$
lattice parameters
a = 0.514 nm
c = 0.744 nm
N = 16 per unit cell

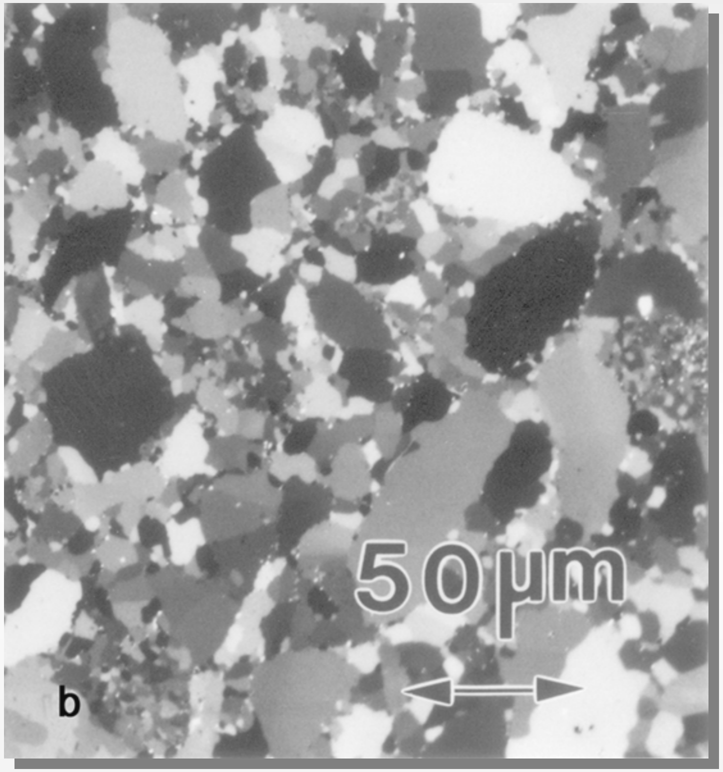
orthorhombic C 54
lattice parameters
a = 0.8267 nm
b = 0.4800 nm
c = 0.855 nm
N = 24 per unit cell

	binding energy (kJ/mole)	melting temperature (K)	Vickers' hardness (load : 1kp) (HV1)
Ti_5Si_3	- 1095 ± 40	2403	970 ± 20
$TiSi_2$	- 687,5 ± 25	1753	870 ± 15

Relation between binding energy, melting temperature and Vickers' hardness

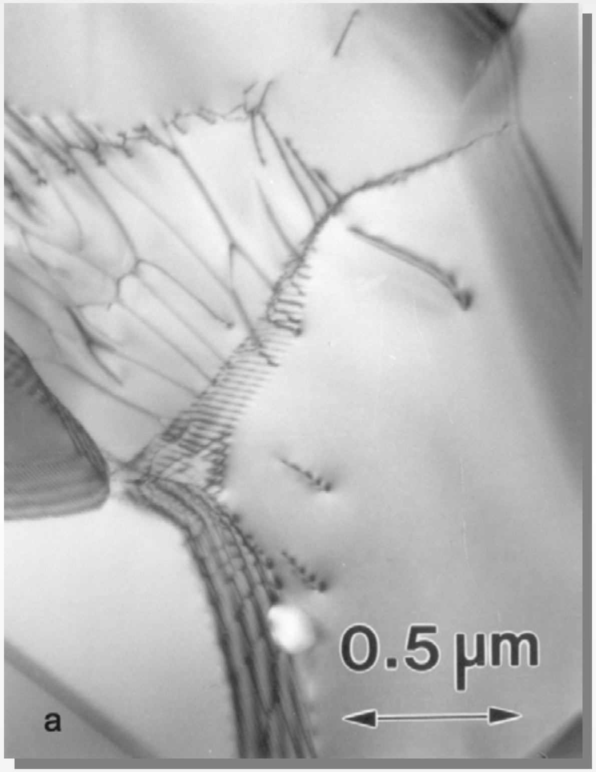


Ti_5Si_3

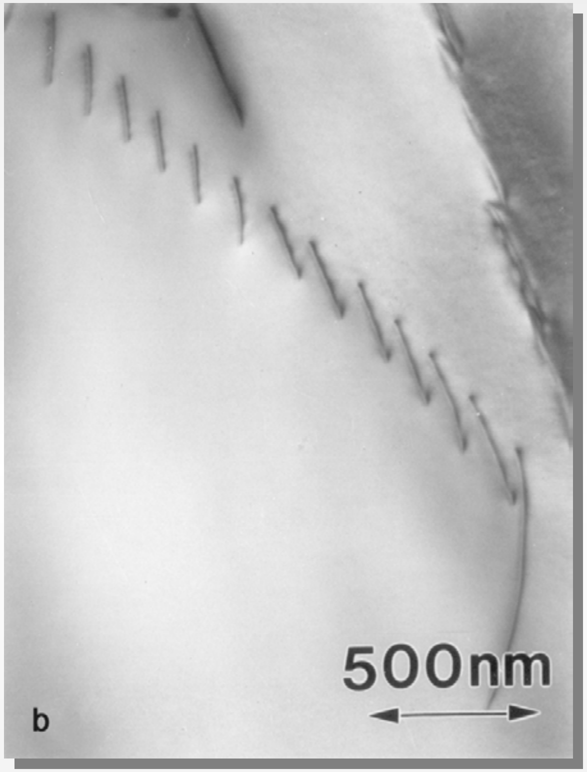


$TiSi_2$

Optical micrographs of as compacted compounds

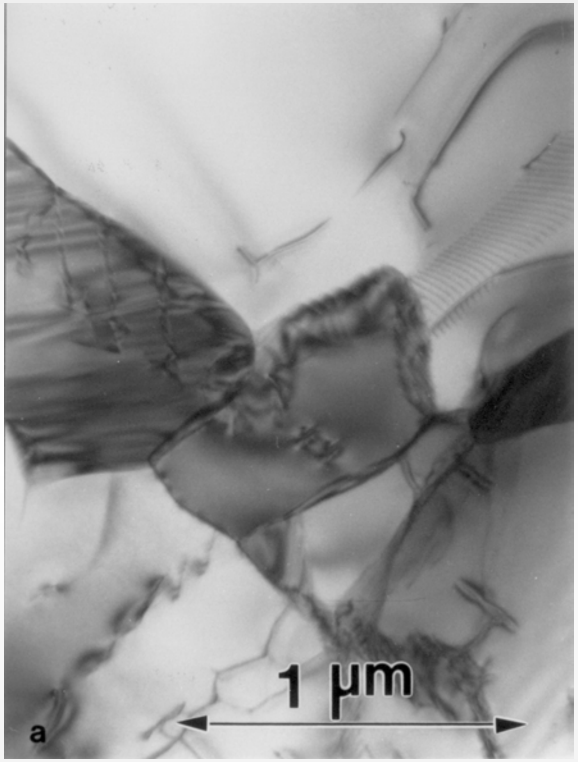


Ti_5Si_3

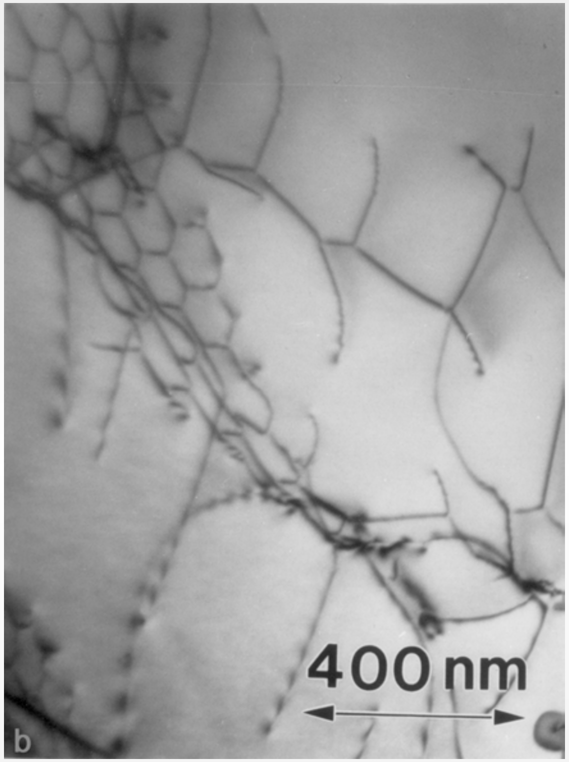


$TiSi_2$

TEM bright field images illustrating the dislocation structures in the as compacted samples



Ti_5Si_3

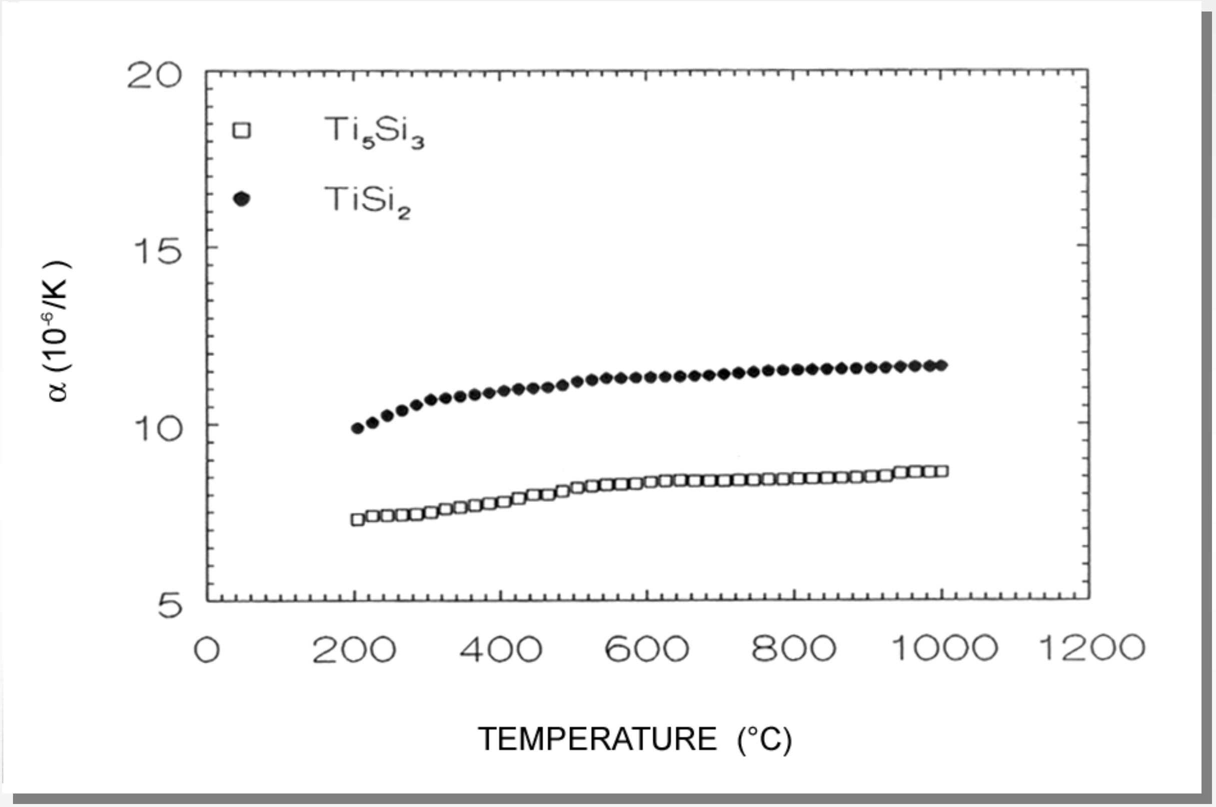


$TiSi_2$

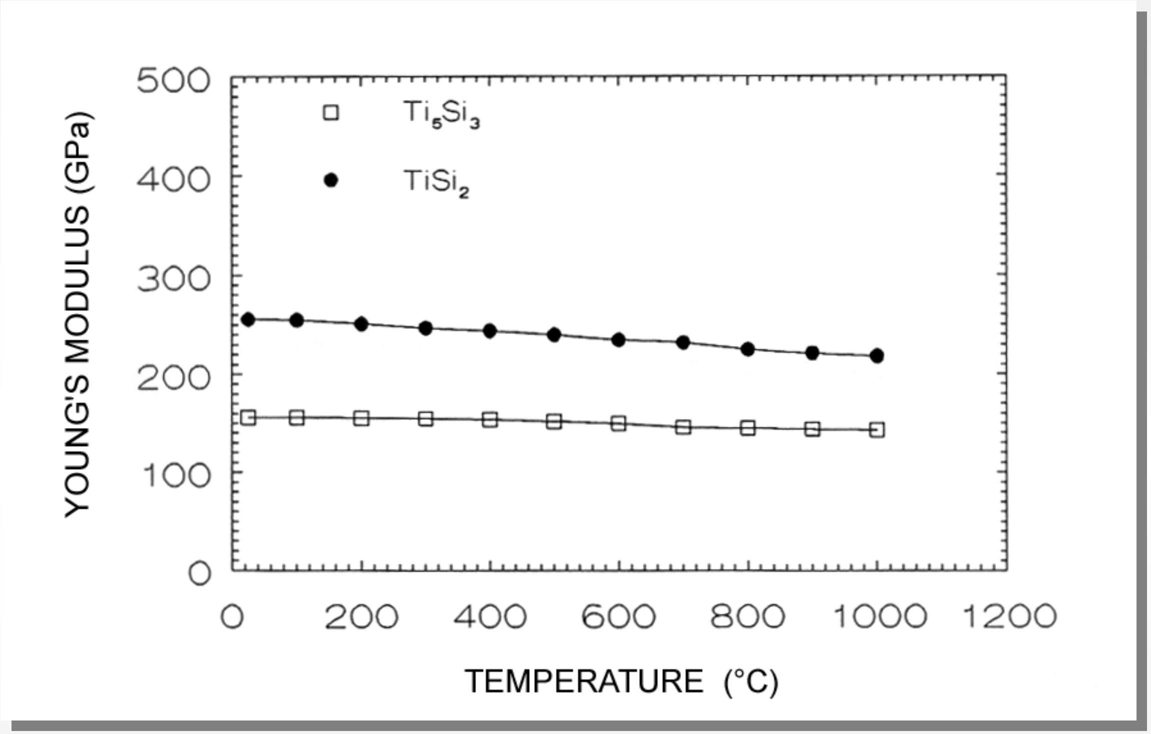
TEM bright field images of creep deformed samples tested at 1000 °C, strain rate $\dot{\varepsilon} = 10^{-7}s^{-1}$

	bulk modulus K(GPa)	Young's modulus E(GPa)	shear modulus G(GPa)
Ti_5Si_3	110 ± 5	156 ± 8	61 ± 3
$TiSi_2$	125 ± 8	256 ± 10	103 ± 5

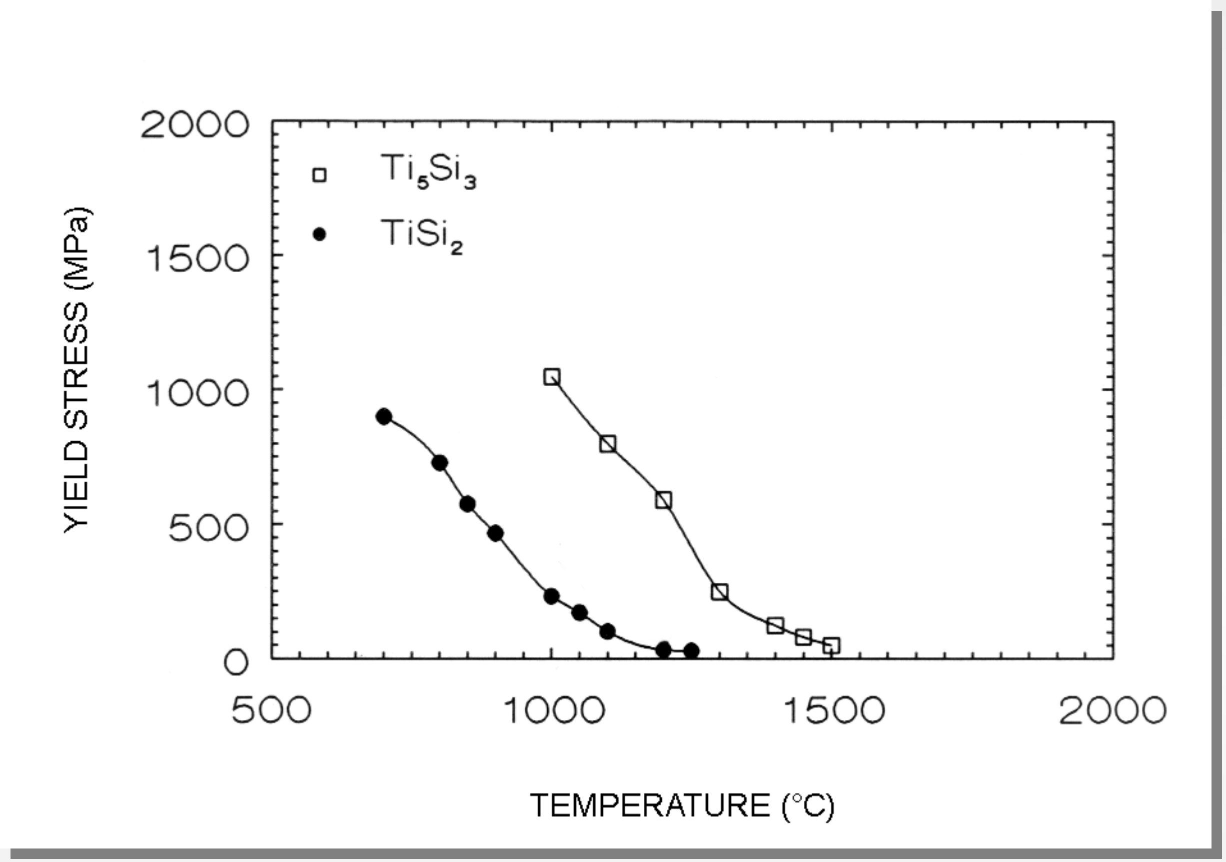
Elastic moduli K, E, G of Ti_5Si_3 and $TiSi_2$ at room temperature



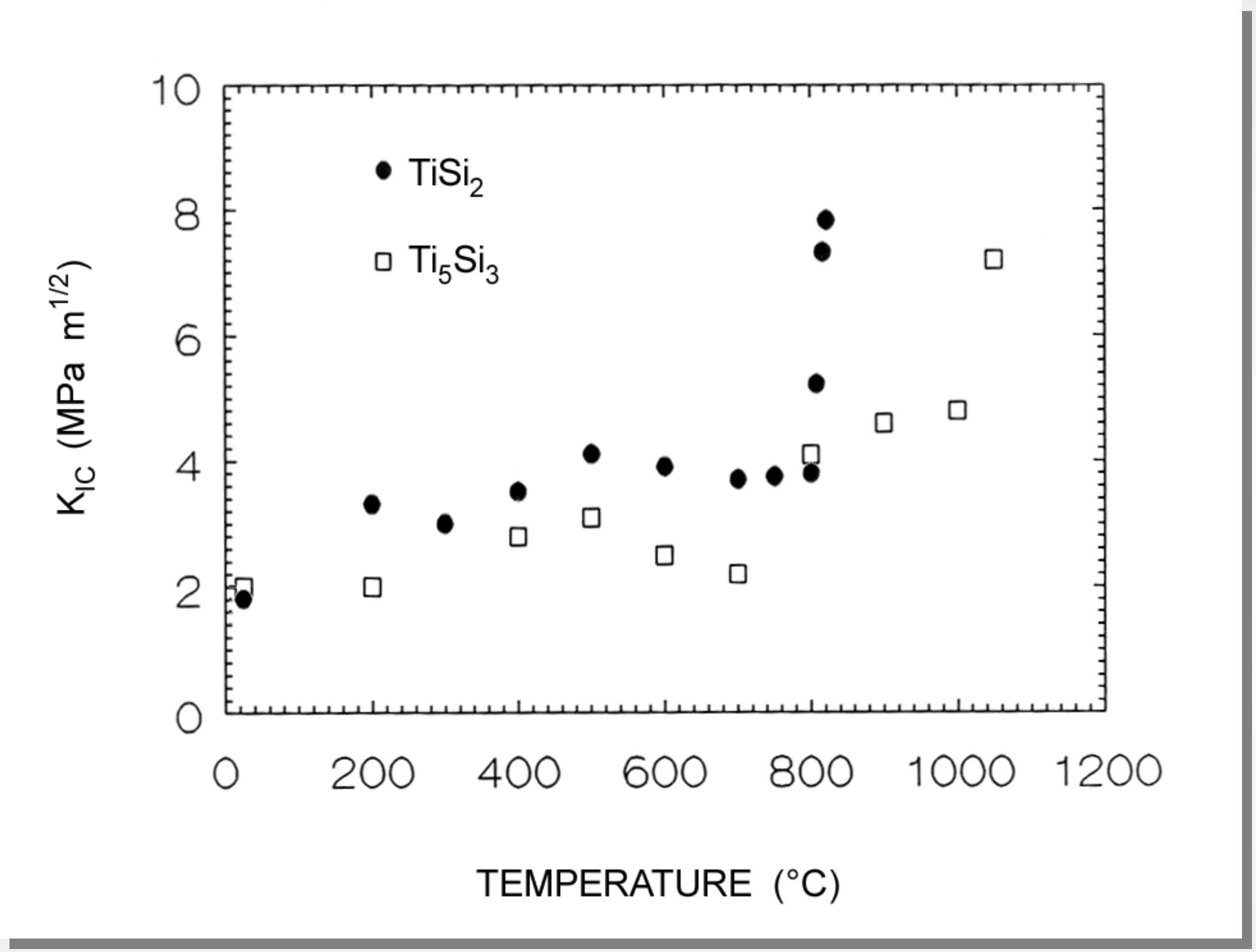
Temperature dependence of the thermal expansion coefficients of the monolithic Ti_5Si_3 and $TiSi_2$ compounds



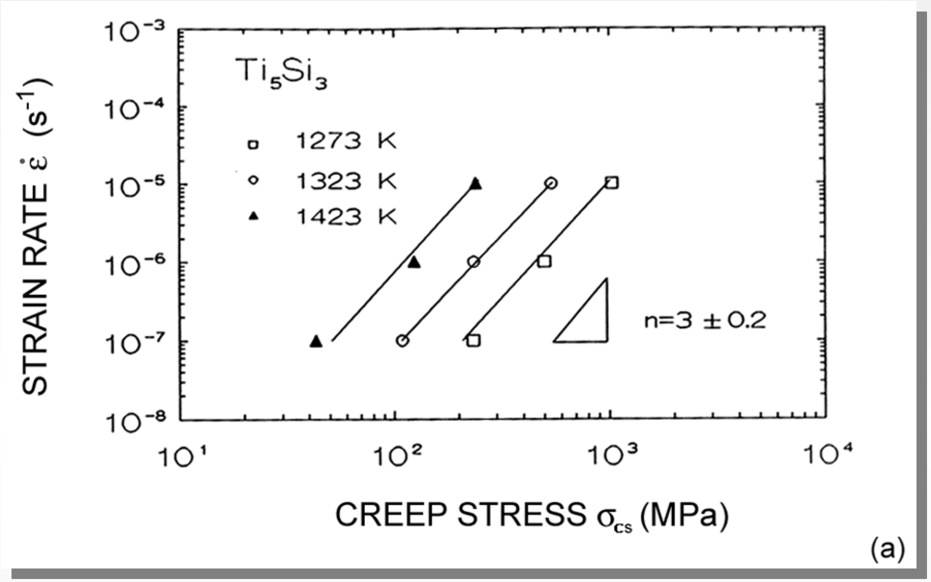
Young's moduli of the monolithic Ti_5Si_3 and $TiSi_2$ compounds as function of temperature

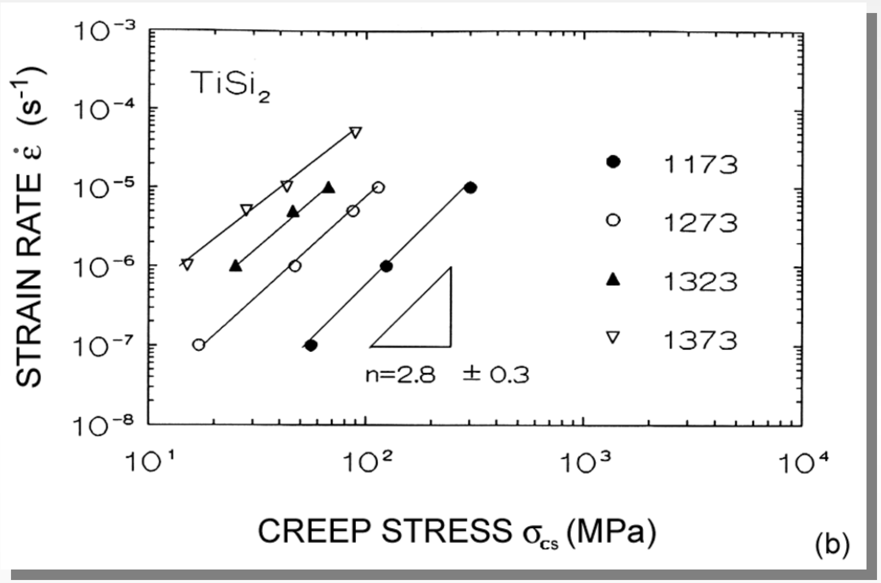


Yield stress vs. test temperature of the monolithic intermetallic Ti_5Si_3 and $TiSi_2$ compounds



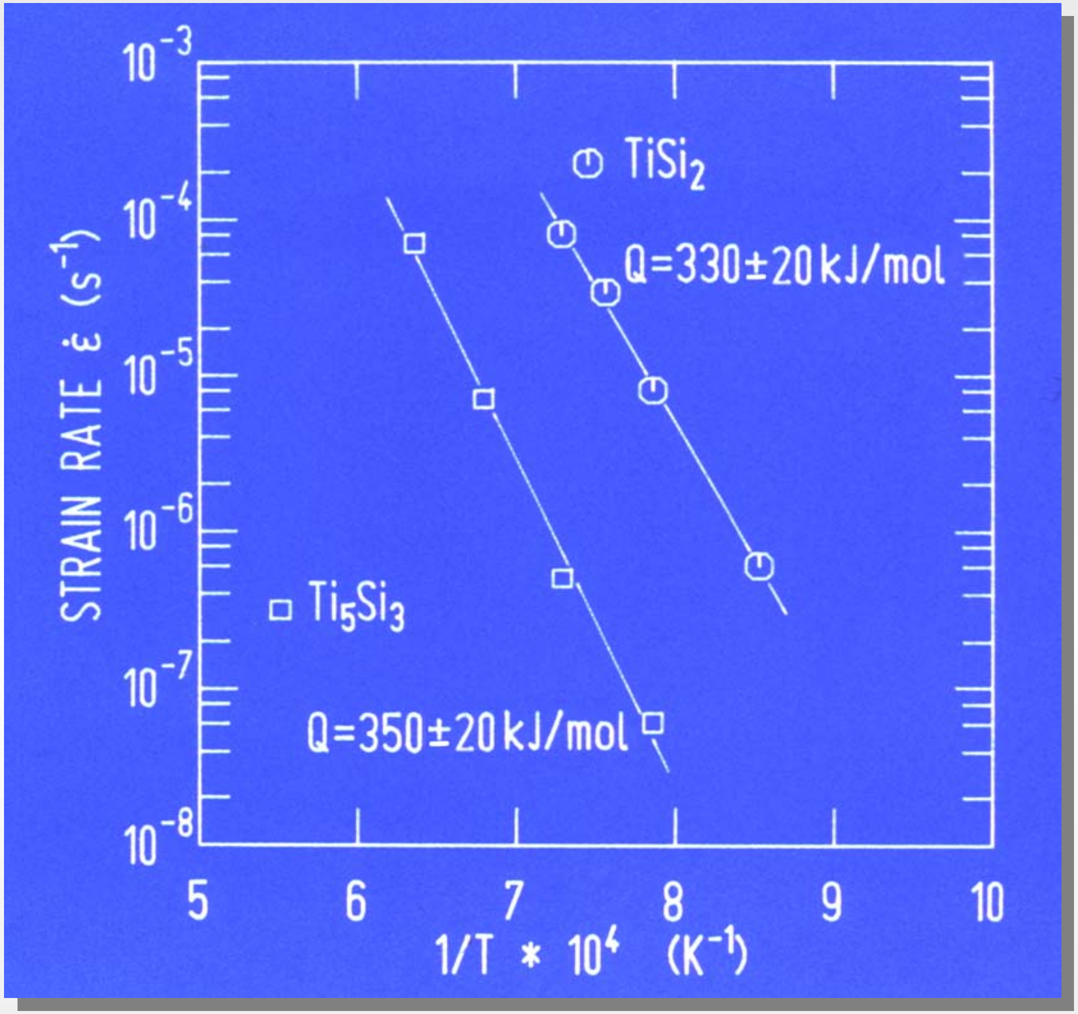
Stress intensity factors of the intermetallic Ti_5Si_3 and $TiSi_2$ compounds as function of test temperature





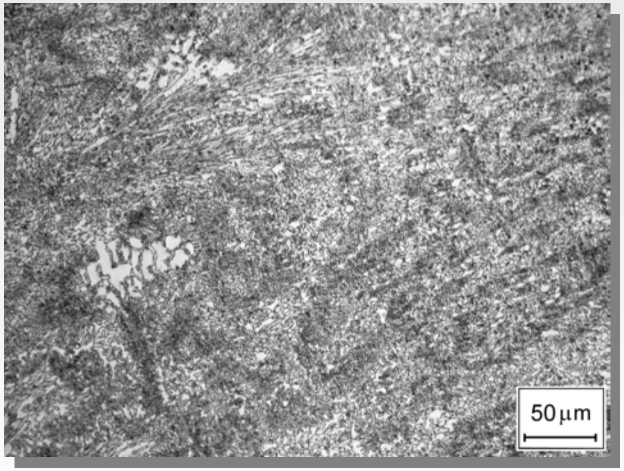
Ti_5Si_3 **$TiSi_2$**

Stress exponent n derived from the slope of the log $\dot{\varepsilon}$ vs. log. σ plot



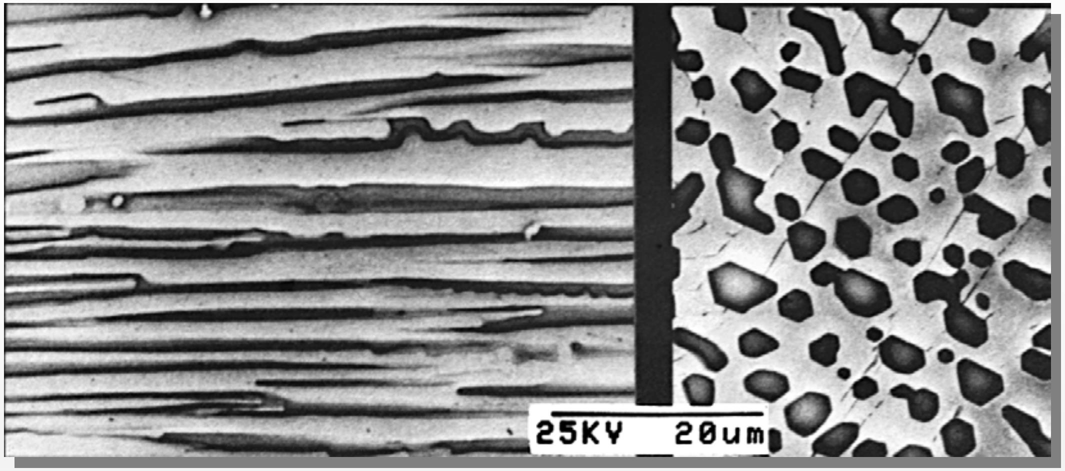
activation energies of Ti_5Si_3 and $TiSi_2$

Powder metallurgically processed air foil of $TiSi_2$
tested in a combustion chamber at 1400 °C for 100 h



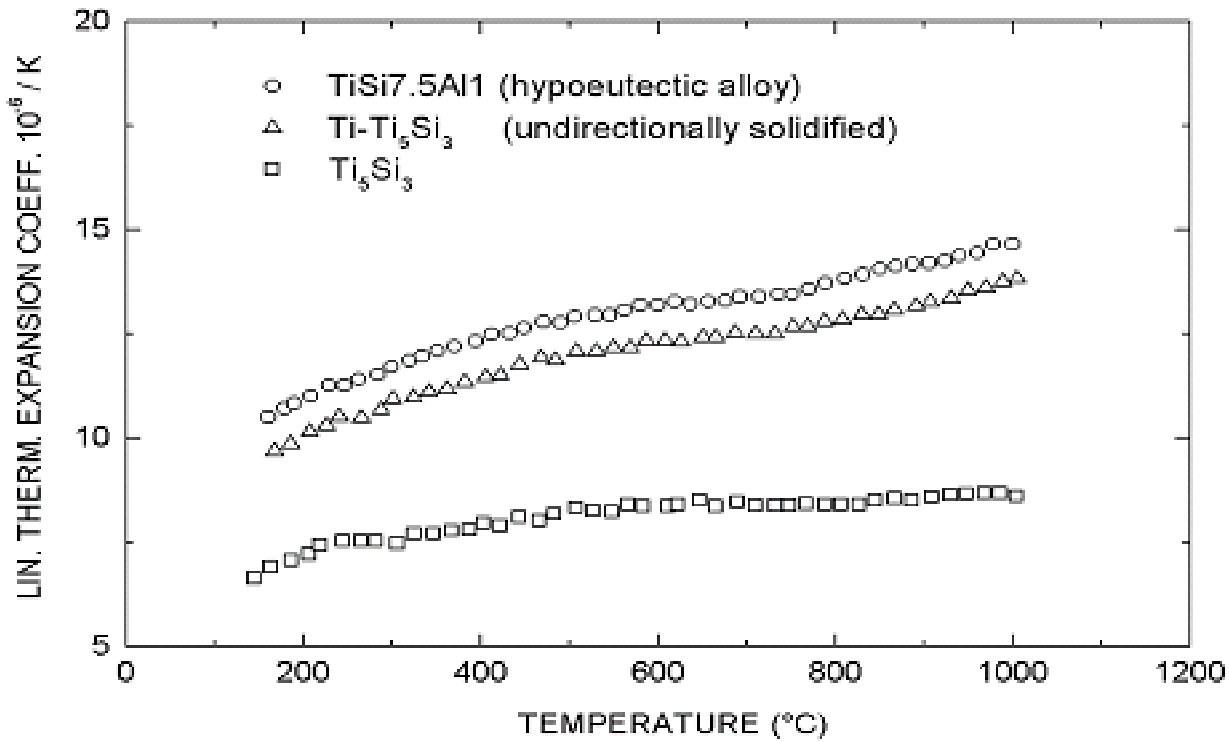
(a)

longitudinal section (b)

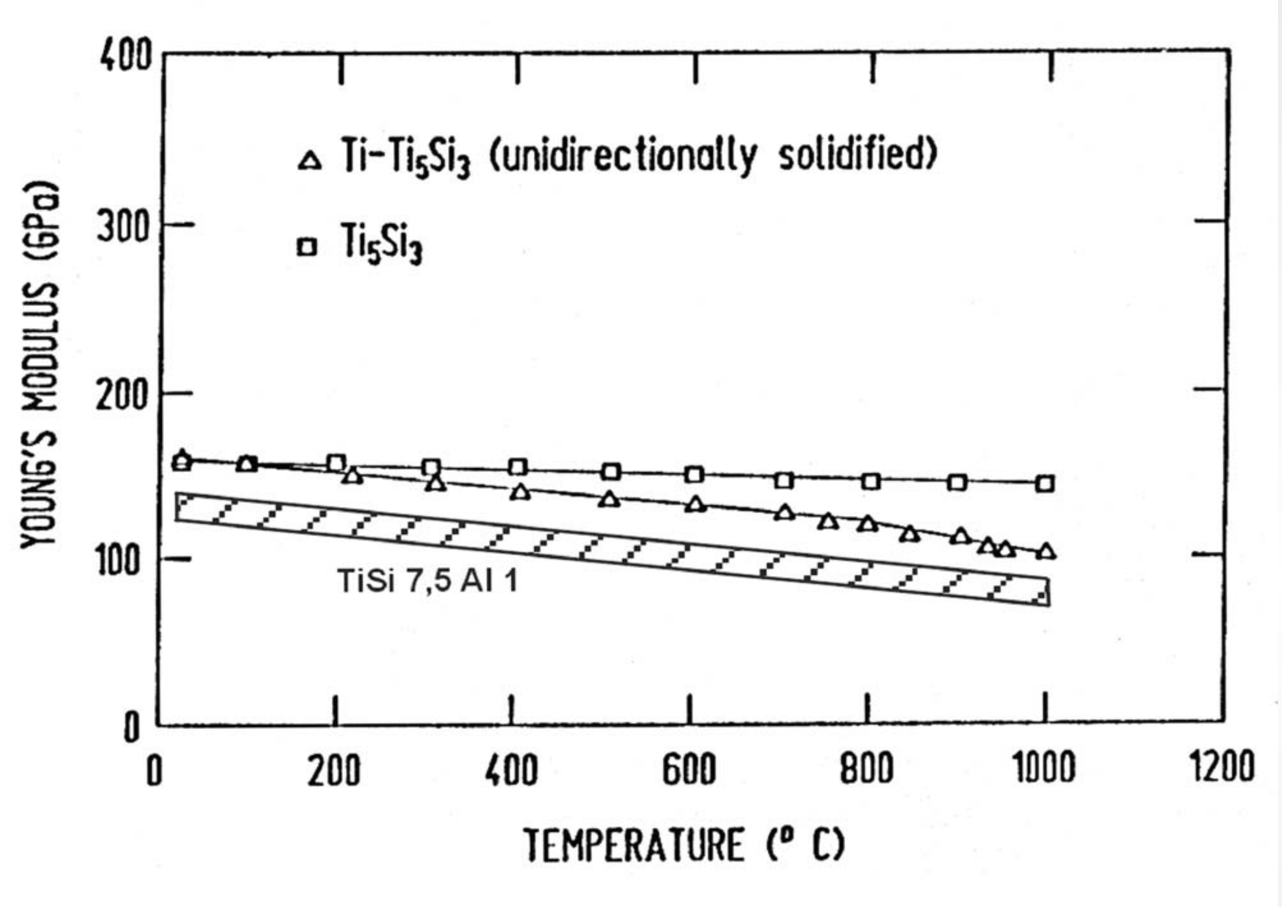


cross section (c)

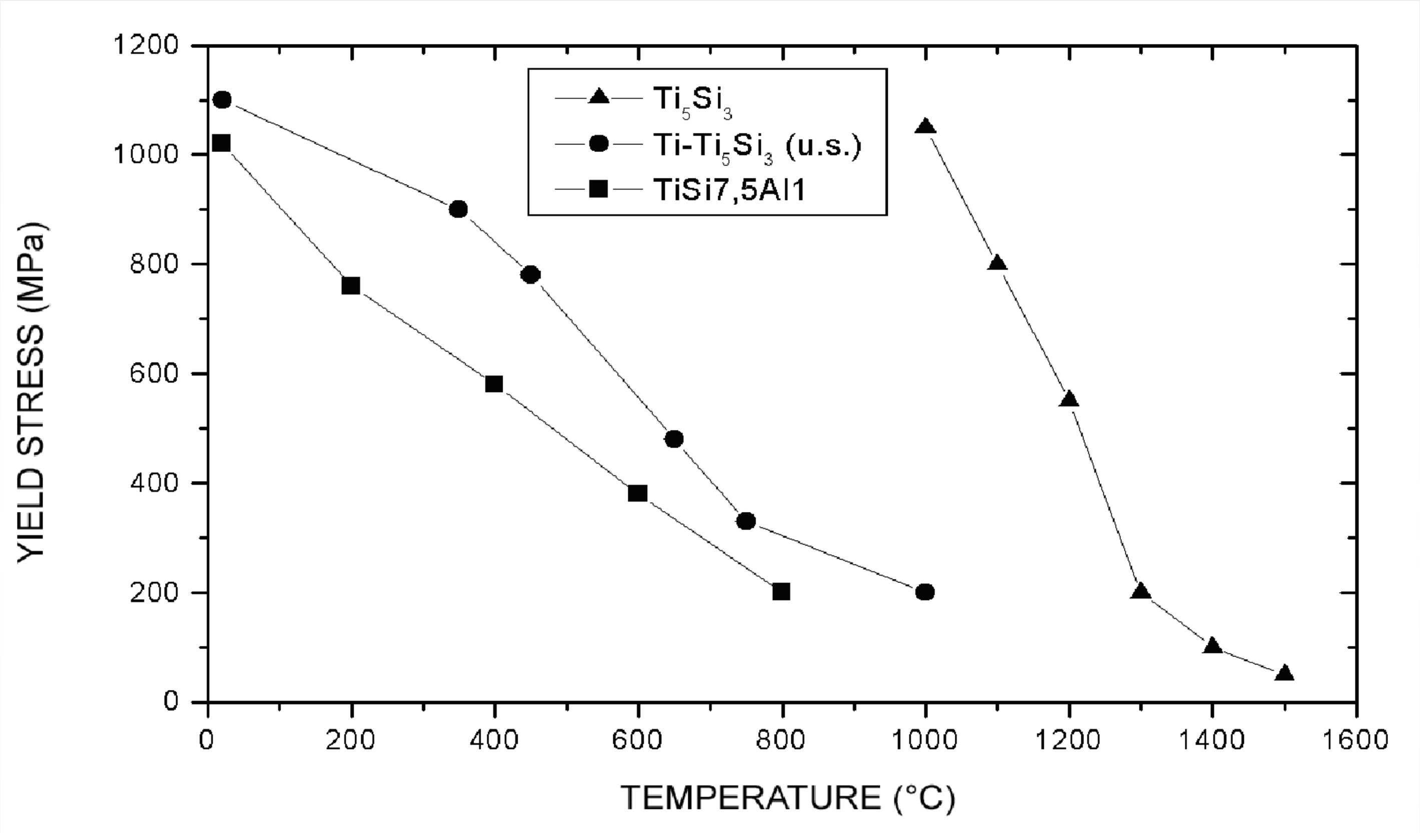
Optical micrograph of the hypoeutectic Ti-7,5Si-Al1 illustrating primary solidified α-Ti solid solution grains (white areas) and fine grained eutectic (a).
SEM micrographs showing the fibre structure of an unidirectionally solidified eutectic Ti-Ti_5Si_3 composite in longitudinal (b) and cross section (c)



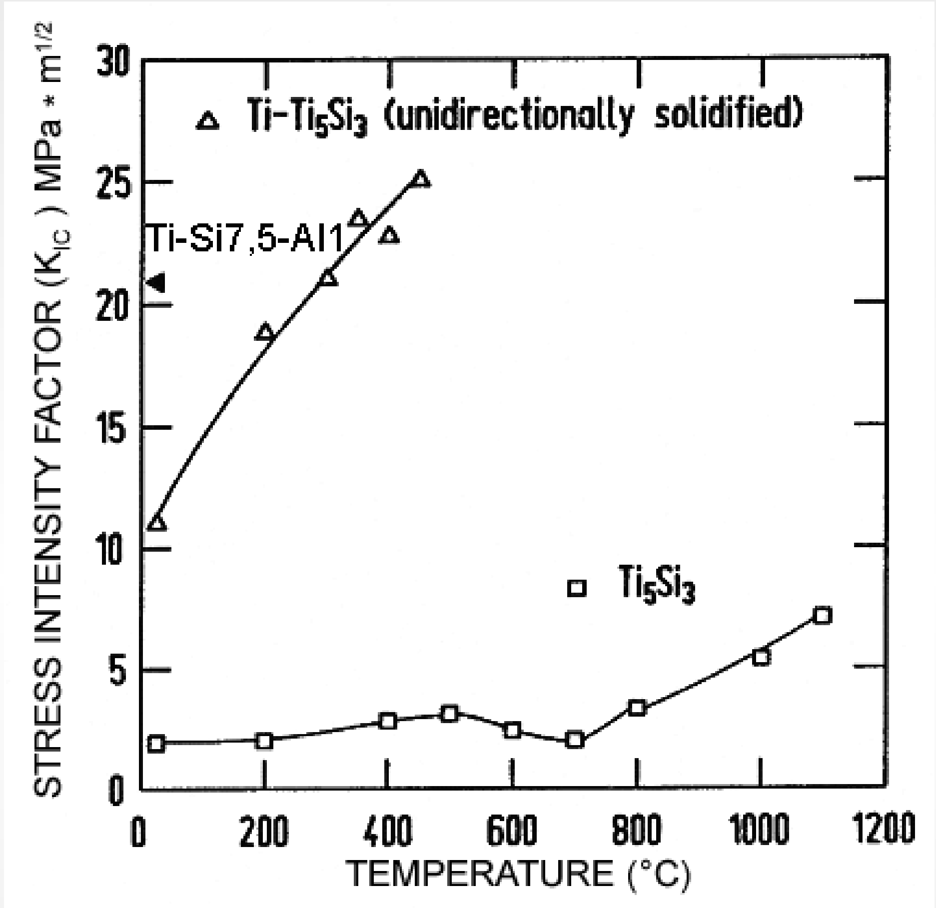
Temperature dependence of thermal expansion coefficients of Ti_5Si_3, the hypoeutectic Ti-Si7.5-Al1 alloy and the unidirectionally solidified eutectic Ti-Ti_5Si_3 composite



Young's moduli of the monolithic Ti_5Si_3 compound and of the hypoeutectic Ti-Si7.5-Al1 and the unidirectionally solidified eutectic Ti-Ti_5Si_3 alloy as function of the test temperature



Yield stress as function of temperature of the hypoeutectic Ti-Si7.5-Al1 alloy and the unidirectionally solidified eutectic Ti-Ti_5Si_3 composite. In comparison the yield stress curve of the Ti_5Si_3 compound is plotted in the diagram.



Stress intensity factors as function of temperature of the hypoeutectic Ti-Si7.5-Al1 alloys and of the directionally solidified Ti-Ti_5Si_3 composite in comparison to the Ti_5Si_3 compound

Summary and Outlook

- Innovative refractory titanium silicides Ti_5Si_3 and $TiSi_2$ exhibit extraordinary physical and mechanical properties and show great potential applications as high-temperature light-weight materials for turbine air foils, heat shield tiles for combustion chambers and missile nozzles.
- The superior oxidation resistance is due to the formation of very stable SiO_2 surface layers
- The high elastic stiffness and hardness of these silicide compounds are caused by the strong covalent bonding of s-p and d-p electron interactions of the Si-Si and S-Ti atoms.
- The prominent high temperature strength, creep resistant and the restricted room temperature ductility are of intrinsic nature. The complex superlattice possess sessile superdislocations of large Burgers‵ vector of high energy.
- For improving the ductility and toughness of silicides micro- and macro alloying have been performed. Alpha titanium – Ti_5Si_3 composites exhibit improved room temperature ductility and combine the advantages of high flow stresses and elevated temperature strength.
- Hypoeutectic and directionally solidified eutectic α-Ti / Ti_5Si_3 composites show considerable potential applications for axial compressor blades and outlet valves in internal combustion engines.